Discovery of Damped Lyman-Alpha Systems at Redshifts Less Than 1.65 and Results on their Incidence and Cosmological Mass Density[1,2]

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ABSTRACT

Damped Lyα (DLA) absorption systems in QSO spectra afford us the opportunity to study the distribution of neutral gas in the Universe back to a time when the Universe was less than 10% of its present age. Since no other methods have revealed large amounts of significantly redshifted neutral gas, it is often stated that DLA absorbers track the bulk of the neutral gas mass of the Universe. On the other hand, DLA systems have a relatively low incidence and, by using traditional QSO absorption-line survey techniques, it has been difficult to identify them at redshifts $z < 1.65$. This is because the needed UV spectra can only be obtained with HST, which is a scarce resource.

In the study described here, we have used HST and an efficient non-traditional (but unbiased) survey technique to discover DLA systems at redshifts $z < 1.65$. Our survey, in the redshift interval $0.1 < z < 1.65$, relies on the observation of Lyα in identified Mg II systems. Their incidence as a function of the Mg II λ2796 rest equivalent is known. With this survey technique, we have uncovered 12 DLA lines in 87 Mg II systems with Mg II rest equivalent width $W_0^{\lambda2796} \geq 0.3$ Å. Two more DLA systems were discovered serendipitously in regions of the spectrum without available Mg II absorption-line information. Since we observe the fraction of Mg II systems with DLA, we are able to determine the incidence of DLA systems at low redshift. By fitting Voigt damping profiles to the Lyα lines in our UV survey spectra, we are also able to deduce the neutral hydrogen column densities of the DLA systems. We then use this information to deduce the low-redshift cosmological neutral gas mass density due to DLA absorbers.

Our survey results indicate the following:

(1) The DLA absorbers are drawn almost exclusively from the population of Mg II absorbers which have $W_0^{\lambda2796} \geq 0.6$ Å. Moreover, if selection criteria which required the rest equivalent width of both the Mg II λ2796 and Fe II λ2600 absorption lines to be $\geq$0.5 Å were adopted, it would be possible to improve the success rate of discovering

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[1]Based on data obtained with the NASA/ESA Hubble Space Telescope at the Space Telescope Science Institute, which is operated by AURA, Inc., under NASA contract NAS5-26555.

[2]Preprint requests can be emailed to rao@everest.phyast.pitt.edu.

DLA systems to $\approx 50\%$. At low-redshift, we know of only one rare case of a DLA absorber that does not fit these selection criteria.

(2) The incidence of DLA systems per unit redshift, n_{DLA}, is observed to decrease with decreasing redshift. The observed trend in n_{DLA} at low-redshift is consistent with the larger incidence of DLA systems seen at high-redshift and the inferred low local incidence for DLA derived from 21 cm observations of gas-rich spirals. Since n_{DLA} is proportional to the number of absorbers per comoving volume times their H I cross-section, the decline in incidence can be interpreted either as a decrease in the effective H I cross-sections of DLA absorbers with decreasing redshift, a decrease in the number of DLA absorbers per comoving volume with decreasing redshift, or a combination of both effects. A decrease in cross-section may correspond to a collapse phase for DLA absorbers, while a decrease in the number of DLA absorbers may be the result of mergers among them.

(3) On the other hand, the cosmological mass density of neutral gas in low-redshift DLA absorbers, Ω_{DLA}, is observed to be comparable to that observed at high redshift. In particular, there is no observed trend which would indicate that Ω_{DLA} at low redshift is approaching the value derived for the cosmological mass density of neutral gas found in present-day spirals, which is a factor of $\approx$6 lower than Ω_{DLA}.

(4) The H I column density distribution of the low-redshift DLA absorber population is found to be very different in comparison to high-redshift DLA absorbers, and in comparison to the column density distribution inferred from local spirals. The low-redshift DLA absorbers exhibit a significantly larger fraction of very high column density systems in comparison to determinations at both high redshift and locally. The observed trend suggests that column density distribution starts out relatively steep at high-redshift, it then flattens at the low redshifts covered in our survey, and then locally it steepens again, becoming even steeper than observed at high redshift. At no redshift does the column density distribution of DLA absorbers fall-off in proportion to $\sim N_{HI}^{-3}$. An $\sim N_{HI}^{-3}$ fall-off is theoretically predicted for disk-like systems and this is, in fact, observed locally in spiral samples.

(5) Thus, the decrease in the overall incidence of DLA absorbers with decreasing redshift, accompanied by the increase in the relative number of high column density systems with decreasing redshift, explains the lack of evidence for evolution in the amount of neutral gas locked up in the DLA absorbers from high to low redshift. This lack of evidence for the conversion of gas into stars (or some other phase), further suggests that the gas contained in discovered DLA systems has not experienced much star formation. This is consistent with metallicity determinations in most high-redshift DLA systems and recent indications which suggest that the galactic-stellar counterparts of low-redshift DLA systems are not luminous spirals. However, this leaves open the question of the present-day whereabouts of the neutral gas mass observed in low-redshift DLA systems.

Aside from the above evolutionary trends, we also discuss possible associated problems caused by small number statistics, dust obscuration, and gravitational lensing bias.

Subject headings: cosmology: observations - quasars: absorption spectra - surveys - galaxies: observations - galaxy formation